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EVALUATION OF THE ENVIRONMENTAL INSTRUMENTS WIND AND TEMPERATURE PROBE IN A WIND TUNNEL AND ENVIRONMENTAL CHAMBER

Report No 88-41-K

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ABSTRACT

The operational usefulness of a recently acquired wind, temperature and relative humidity probe was investigated in a wind tunnel facility at AES and an environmental chamber at Ontario Hydro Research Division. The probe provides satisfactory measurements under non-freezing conditions. Further tests are required to assess the capabilities of the probe under icing and field conditions.

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Dr. D. Mills
Director of Research

EVALUATION OF THE ENVIRONMENTAL INSTRUMENTS WIND AND TEMPERATURE PROBE IN A WIND TUNNEL AND ENVIRONMENTAL CHAMBER

1.0 INTRODUCTION

The Environmental Science Section of Research Division has recently acquired a solid state automatic wind and temperature measurement system from Environmental Instruments Inc. This system, referred to as the EII probe, consists of a probe, a digital signal processor, cable and a heated de-icer.

It has long been recognized that local wind and temperature fields are important for various environmental applications. It is also recognized that information on humidity is required when studying precipitation and condensation processes. The EII system is a prototype system designed to facilitate measurement of these meteorological variables.

The probe was received from the supplier on February 24, 1987 and was immediately set up for testing in the laboratory and in the field. In both tests the probe was compared with existing instruments such as a Campbell Scientific weather station and a psychrometer. The results agreed favourably well.

The probe was then used as part of the instrumentation package for the 1987 field study of freezing precipitation and fog events in the vicinity of Trafalgar TS. It was installed at a level of about 26 m above the ground on a microwave tower. A built-in heater was turned on during the study to prevent accumulation of snow or ice during the study period. After the study the probe was removed from the microwave tower and used to measure wind and temperature during the tritium study at Chalk River. During that study, the probe was mounted on a pole at a level of about 1 m above the ground.

Measurements from both of these two studies indicated that the EII temperatures were higher by 1 to 2°C than the Campbell Scientific weather station temperatures. Intermittent fluctuations were also observed in the visual displays of the wind measurements.

The usefulness of this probe depends on its accuracy and reliability. To assess this, a series of calibrations and comparisons was performed in a wind tunnel and a controlled environmental chamber. This report summarizes the results.

2.0 EXPERIMENTAL

2.1 The EII Wind and Temperature Probe

The EII wind and temperature probe, as shown in Figure 1, is constructed in a way that allows operation under the most severe environments. The sensors are made by thermal resistive film transducers which, according to the manufacturer, are immune to shock, vibration and contamination and thus, can retain their electronic characteristics indefinitely.

Winds are measured by a pair of film sensors which are stacked at right angles to each other for sensing the two components of the wind vector (x and y). Wind speed and wind direction are calculated from the magnitude of the two orthogonal signals.

The temperatures and relative humidities are also measured by a film sensor but with a temperature coefficient of resistance adjusted to compensate the wind-sensing pair for variations in ambient temperature. Some key specifications of the probe are given in Table I.

The probe is equipped with a digital signal processor in which a signal conditioner is used to resolve automatically the x and y components of wind speed and wind direction. Both digital and analog outputs of wind speed, wind direction, temperature and relative humidity are displayed in the processor.

2.2 The AES Wind Tunnel

The performance of the EII wind sensor was tested in the Atmospheric Environment Service wind tunnel. This wind tunnel facility is a so-called enclosed open-circuit system. As shown in Figure 2, the facility contains a tunnel duct, a drive system and a return duct. The tunnel is fabricated of wood with glass windows for observation purposes. The working test section is 18 m long with a cross-section of about 4.5 m^2 (2.5 m horizontal and 1.8 m vertical).

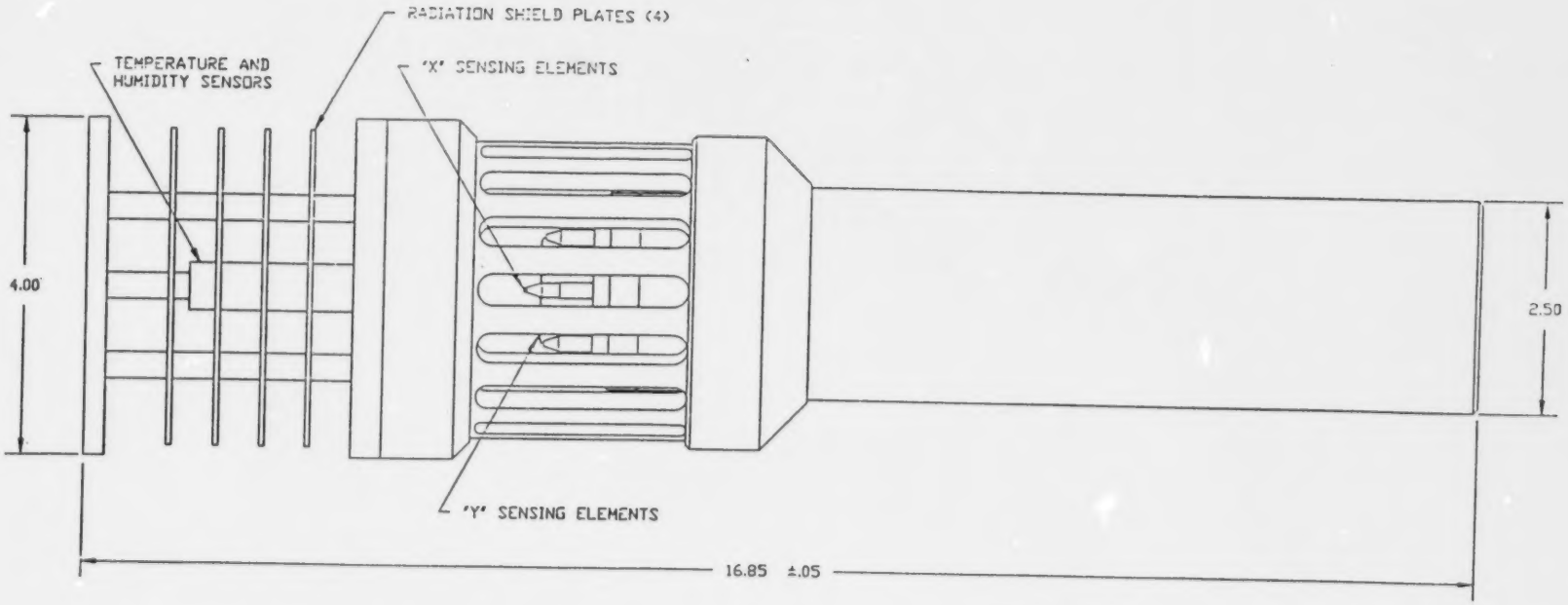


Figure 1

A schematic picture of the EII wind and temperature probe

TABLE I

SPECIFICATIONS OF THE EEI WIND AND TEMPERATURE PROBE

Wind

range:	0 to 50 m/s (speed) 0 to 360 (direction)
low speed threshold:	0.05 m/s
accuracy:	±3%
response time:	instantaneous
operating temperature:	-40 to +70°C

Temperature

range:	-100 to +150°C
accuracy:	±0.5°C
response time:	instantaneous

Humidity

range:	0 to 100%
accuracy:	±2%
response time:	instantaneous

Sensor Type

wind:	platinum film
temperature:	platinum RTD
humidity:	converter module

Electrical Characteristics

input power:	24 V dc or 110/220 V ac
power requirement:	2 A
analog output signals:	0 to 10 V dc

Physical Characteristics

probe height:	26 cm
probe weight:	1.4 kg
probe finish:	black anodized aluminum

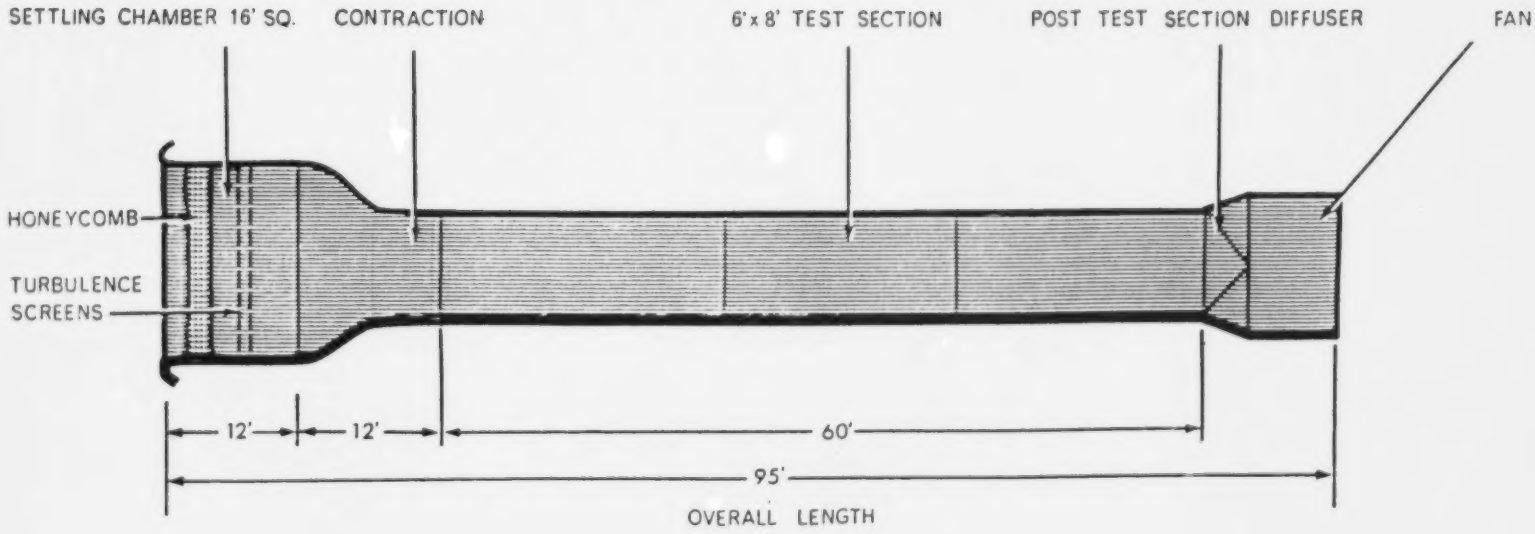


Figure 2

A schematic picture of the AES wind tunnel facility

The air flow in the facility is generated by the tunnel fan which is driven by a 75-hp electrical motor. The range of the wind speed is from 0 to a maximum of about 20 m/s in the working test section. These ranges are adjusted by a set of vanes located immediately downstream of the fan. The tunnel room acts as the return duct of the facility.

The facility is equipped with control and record units to monitor the air speed and temperature. During the present tests, the air speed was monitored by a micro-manometer while the temperature was measured by a copper-constantan thermocouple located next to the EII probe in the working test section. The EII probe was mounted on a pole which was secured by a rotor right beneath the working section. The rotor could be rotated 360 degrees with a very fine increment for testing the sensitivity of the wind direction component of the probe.

Since the wind tunnel tests were aimed mainly at testing the wind measurement capability of the probe, the air temperature measurements were used merely as supporting information.

3.0 PRESENTATION OF RESULTS

Table II summarizes the various tests conducted with the EII wind sensor. Basically, the wind sensor was tested for two distinct air speeds, 5 m/s and 10 m/s. All tests were performed under similar conditions of temperature (23 to 24°C) and relative humidity (30 to 31%).

During the tests, the EII wind sensor was set up in the centre of the working test section of the wind tunnel, at a level of about 1 m above the tunnel floor. The sensor was connected to both the EII data processor and AES control and record unit, so that the measurement could be compared.

As seen in Table II, Tests 1,2,5 and 6 were performed to calibrate the wind direction while Tests 3 and 4 dealt with the wind speed. The test results are given in Appendix A.

A comparison of the EII wind speed and the tunnel wind speed is illustrated in Figure 3. As seen from the figure, when the EII probe was facing the air flow (360 degrees), Figure 3(a), it underestimated the wind speed by 4-25%. When the air flow was

TABLE II

SUMMARY OF THE VARIOUS TESTS PERFORMED IN THE AES WIND TUNNEL

Test No	Air Speed (m/s)	Air Direction (degrees)	Air Temperature (°C)	Air Humidity (%)
1	5.0		23.3	31.0
2	10.0		23.5	31.0
3		360	23.8	30.0
4		225	23.8	31.0
5	5.0		23.8	31.0
6	10.0		23.8	31.0

TABLE III

SUMMARY OF THE VARIOUS TESTS PERFORMED IN THE ENVIRONMENTAL CHAMBER AT RESEARCH DIVISION

Test No	Air Speed (m/s)	Air Direction (degrees)	Air Temperature (°C)	Air Humidity (%)
1	1.0	330	10.0	50.0
2	1.0	330	20.0	50.0
3	1.0	330	5.0	50.0

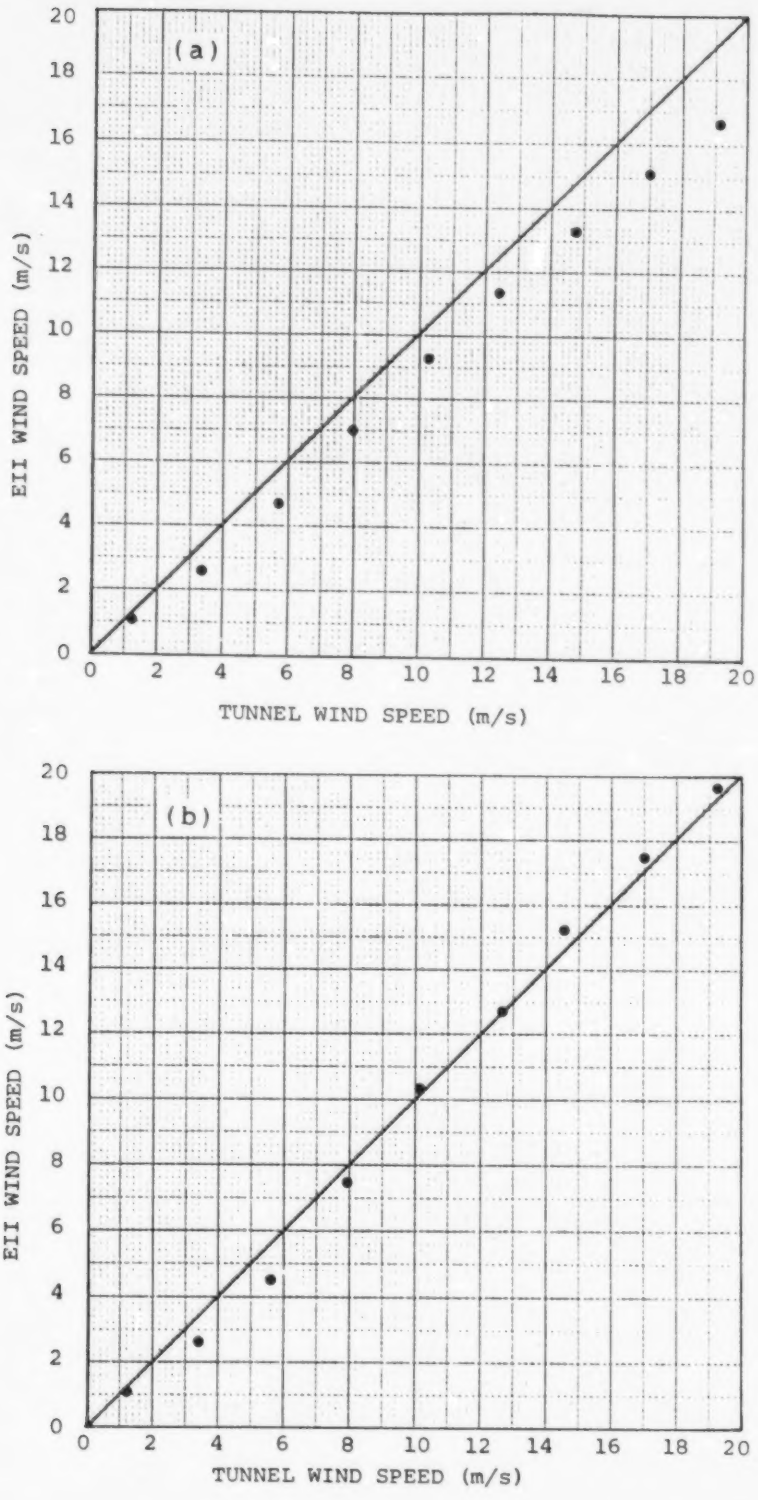


Figure 3

EII wind speed vs wind tunnel wind speed
(a) wind from 360 degrees; (b) wind from 225 degrees

from 225 degrees, Figure 3(b), the wind speed measured by the EII probe was underestimated, at wind speeds lower than about 8 m/s, but overestimated at wind speeds higher than about 14 m/s. The underestimation ranged between 6 and 24% while the overestimation was only 1 to 4%.

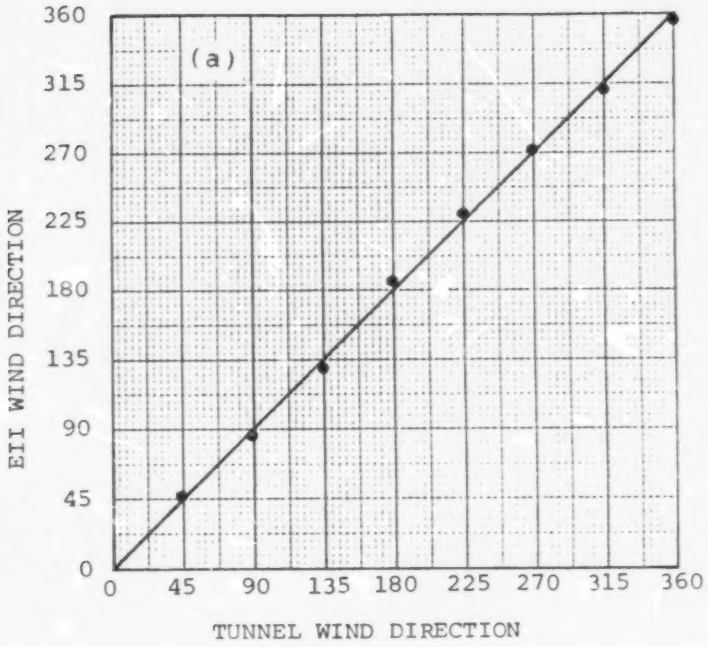
Figure 4 displays the comparison of the EII probe wind direction and the tunnel wind direction. Note that these tests were performed under identical conditions of temperature (23.8°C) and relative humidity (31%) with air speeds of 5 and 10 m/s. It can be seen that both measurements corresponded remarkably well with each other.

The temperature and humidity tests were carried out in a controlled environmental chamber at Research Division. A summary of the various temperature and humidity tests is given in Table III. During the tests, the EII probe temperature measurements were compared with the chamber temperature and those measured by a psychrometer. The relative humidity, on the other hand, was compared with the calculated value derived from the psychrometer readings. All the measurements agreed with each other. A list of the test results is given in Appendix B.

4.0 DISCUSSION

The EII wind and temperature sensor has been tested to determine its accuracy and limitations. The wind measurements were tested in AES's wind tunnel facility while the temperature and humidity measurements were tested in an Ontario Hydro Research Division environmental chamber.

Results from the tests indicate that the EII probe in general performs satisfactorily. However, the wind speed response is slightly low when the wind is from 360 degrees. A slight underestimation is also observed when the wind is from 225 degrees and below about 8 m/s. This under-estimation is thought to be attributable to the configuration of the probe itself. Temperature and relative humidity measurements made with the probe agreed very well with experimentally set values.



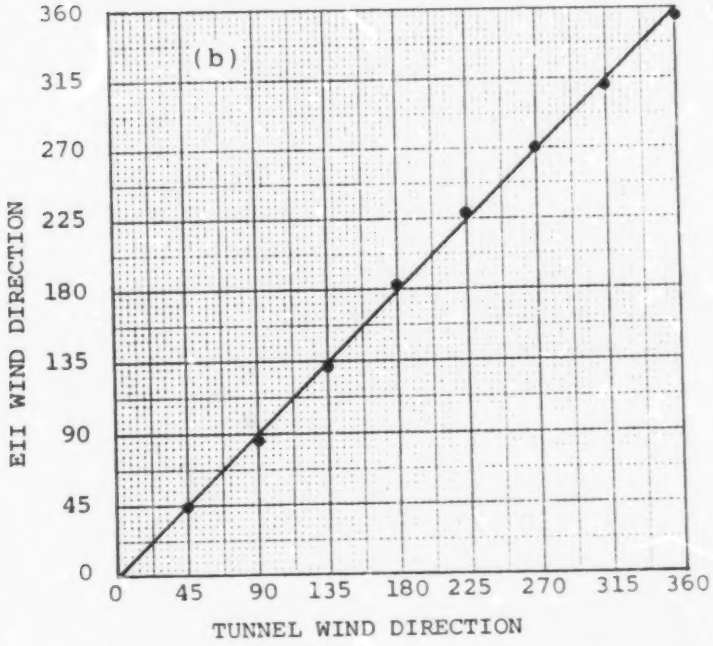


Figure 4

EII wind direction vs wind tunnel wind direction
(a) wind speed @ 5 m/s; (b) wind speed @ 10 m/s

The EEI probe appears to be an excellent candidate for routine meteorological measurements. As the tests indicate it is relatively accurate and is claimed to be rugged, and able to operate even under icing conditions. The assessment of the probe's performance under field conditions is continuing. As well, tests in an icing wind tunnel are being discussed.

ACKNOWLEDGEMENTS

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APPENDIX A

TEST RESULTS FOR THE EII WIND SENSOR AT AES's WIND TUNNEL

SENSITIVITY TEST OF THE EII WIND SENSOR

Test 1:
- constant wind speed @ 5 m/s
- the wind direction was adjusted from inside the tunnel
- tunnel temperature @ 23.3°C
- tunnel relative humidity @ 31%

Wind Speed (m/s)		Wind Direction	
Tunnel	EII	Tunnel	EII
5.66	4.7	0	359.8
5.69	4.7	90	91.1
5.63	4.2	180	186.5
5.69	5.5	270	273.3
5.63	4.7	360	356.0

Test 2:
- constant wind speed @ 10 m/s
- the wind direction was adjusted from inside the tunnel
- tunnel temperature @ 23.5°C
- tunnel relative humidity @ 31%

10.26	9.5	0	358.7
10.26	9.5	90	88.2
10.26	8.8	180	181.6
10.26	9.9	270	271.1
10.22	9.3	360	358.7

SENSITIVITY TEST OF THE EII WIND SENSOR (cont'd)

Test 3:
- various wind speeds
- constant wind direction from 360 degrees
- tunnel temperature @ 23.80°C
- tunnel relative humidity @ 30%

Wind Speed (m/s)		Wind Direction	
Tunnel	EII	Tunnel	EII
1.20	1.15	360	341.5
3.40	2.54	360	354.0
5.69	4.73	360	357.7
7.96	7.05	360	358.5
10.26	9.35	360	359.5
12.45	11.35	360	360.0
14.80	13.31	360	0.2
17.00	15.10	360	0.3
19.20	16.57	360	0.4

Test 4:
- various wind speeds
- constant wind direction from 225 degrees
- tunnel temperature @ 23.8°C
- tunnel relative humidity @ 31%

1.20	1.03	225	237.2
3.43	2.59	225	228.8
5.69	4.49	225	224.1
7.98	7.53	225	224.7
10.20	10.26	225	224.9
12.78	12.77	225	225.0
14.60	15.20	225	225.0
17.00	17.56	225	225.0
19.20	19.61	225	225.0

SENSITIVITY TEST OF THE EII WIND SENSOR (cont'd)

Test 5: - constant wind speed @ 5 m/s
- the wind direction was adjusted from outside the tunnel

Wind Speed (m/s)		Wind Direction	
Tunnel	EII	Tunnel	EII
5.67	4.9	0	356.8
5.60	4.8	45	46.2
5.54	5.0	90	87.5
5.47	4.6	135	132.5
5.45	4.7	180	182.9
5.62	5.3	225	230.4
5.66	5.7	270	271.9
5.59	5.0	315	310.7
5.58	4.8	360	356.6

Test 6: - constant wind speed @ 10 m/s
- the wind direction was adjusted from outside the tunnel

10.22	9.4	0	358.8
10.16	10.5	45	45.0
10.09	9.7	90	88.8
10.06	10.0	135	134.1
10.00	8.8	180	181.6
9.97	10.8	225	228.8
9.76	10.2	270	270.4
10.22	10.7	315	313.1
10.28	9.4	360	358.7

APPENDIX B

RESULTS FOR THE EII TEMPERATURE AND HUMIDITY SENSOR TESTS AT ONTARIO HYDRO RESEARCH DIVISION ENVIRONMENTAL CHAMBER

SENSITIVITY TEST OF THE EII TEMPERATURE SENSOR

TEST 1:
- constant wind speed @ 1 m/s
- constant wind direction @ 330
- chamber temperature @ 10°C
- chamber relative humidity @ 50%

Temperature (°C)		Relative Humidity (%)	
EII	Psychrometer	EII	Psychrometer
10.9	11.0	58	57
11.0	11.0	58	57
11.0	11.0	58	57
11.0	10.9	58	57
11.2	10.9	57	57
11.2	10.9	57	57
10.9	10.9	58	57
10.9	10.9	58	57
10.9	10.9	58	57
10.9	10.9	58	57
11.0	11.0	57	57
11.0	11.0	57	57

Test 2:
- constant wind speed @ 1 m/s
- constant wind direction @ 330
- chamber temperature @ 20°C
- chamber relative humidity @ 50%

Temperature (°C)		Relative Humidity (%)	
EII	Psychrometer	EII	Psychrometer
20.2	20.0	49	51
20.0	20.0	47	51
20.0	20.0	47	48
20.0	20.0	45	48
20.0	20.0	45	48
20.1	20.2	44	47
20.3	20.3	45	47

SENSITIVITY TEST OF THE EEI TEMPERATURE SENSOR (cont'd)

Test 3:
- constant wind speed @ 1 m/s
- constant wind direction @ 330
- chamber temperature @ 5°C
- chamber relative humidity @ 50%

Temperature (°C)		Relative Humidity (%)	
EII	Psychrometer	EII	Psychrometer
4.9	5.0	55	57
5.0	5.0	55	57
4.9	5.0	55	57
5.0	5.0	55	57
4.9	5.0	56	57